Electronic Systems for Cancer Diagnosis
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Lecture – 07
Photolithography: Mask Aligner

Hi, welcome to this particular class. And this class is focused on designing a Mask Aligner. Now, what we have learned in the previous class is what is photolithography right. And we have seen I think M J before, operation of M J before mask aligner using the video that we had. And I am show that you now know how the photolithography works, what are the positive photoresist, what are negative photoresist, what are bright film masks, what are dark film mask, how to align the wafer right.

Now, to align the wafer, mask aligner right; and to expose the wafer UV source right. So, the cost of this system right now is close to like 50 lakh. And we have MEMS based sensors or design or technology related to course in lot of universities, isn't it. We learn it right, we learn it through books, but not all of us are having a setup within our university that we can go and see whatever we study in the book, how it looks like right. And to bridge that gap, we need to develop a technology, so that every university can adopt a system which is at lower cost.

So, here in this particular lecture, I will be telling you something related to what I am doing in my laboratory. And this is also a part of this lecture, because mask aligner or photolithography is integral part of any MEMS based sensor. Now, what we are doing right, we want to reduce the cost of the mask aligner traditional mask aligner to a value that most of the universities, most of the colleges can afford right.

If we see that photolithography processes, you take the wafer, how wafer looks like, you can buy your wafer it is like 700 rupees close to 2000 rupees. Now, once you have the wafer right, what you will do with that? If you do not want to buy wafer, you can buy a glass, glass slide that is also is fine right.

What is a photolithography step? Photolithography steps are first you clean the substrate, second coat the primer, so you need a small spin coater. There are varieties of spin coater available in market at lower price, you can get one. Spin coat photoresist, first we can

spin coat primer or we can spin core photoresist. After spin coating photoresist, we have to prebake, you can buy a hot plate, there should be hot plate in any chemistry lab in biology labs, you put the wafer.

So, again you have to perform all these thing in a yellow room small room which is required to avoid the UV light, so that the photoresist will not get exposed to UV before we actually align the align the substrate coated with photoresist. So, what we require, we after we spin coat photoresist, then you have to use a mask, and load the mask on the mask aligner, and expose it, then you have to have developer small (Refer Time: 04:27).

And then I think the if you have a metal, you have to use the metal right now you know the steps. So, how about we developed our own mask aligner and at a way reduced cost, and that can perform photolithography step to get your design at least a simple design like a heater. Then you can connect that with the theory, and probably understand how the photolithography system works, so that is the idea behind developing a mask aligner within my laboratory.

Now, when I will be teaching you this mask aligner steps, you will also know and learn that you can also do the same thing in your university; try, take it as project and try it right. We should start finding an alternative solutions, if we cannot afford a particular technology right develop your own technology right.

We have to start developing things here in our country, it is a high time we use the knowledge that we have, and put it together to develop technologies that are cheaper, that are affordable that that can go to the market, that can go to the universities, and all of us can get a better exposure to the education that we really deserve right.

Having said that I am not telling that we are not getting enough exposure right, all of us, all teachers, and the management are trying best I am sure we are trying best to our abilities to help you out to understand the technology as much as we can help you, but the lacking, the gap that lies is to show you the technology.

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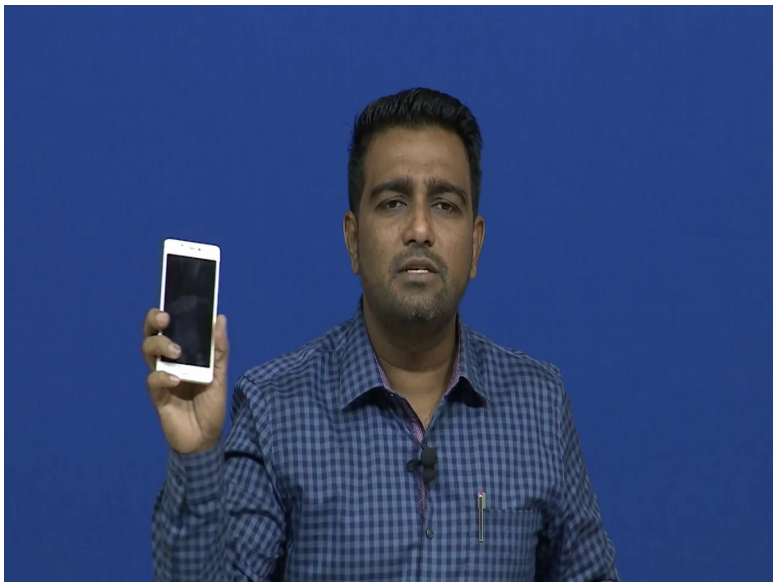

If I talk about mobile, mobile, mobile, mobile is this, mobile can do this, mobile can send SMS, mobile can we can we can access a lot of social network on mobile, we can talk on mobile, and we can see videos on mobile, but I do not show you the mobile. Then but what if I just show you a simple mobile ok, this is a mobile, this is how it operates, these are button right, this is how you can use it, its easier know that is the idea, that show whatever we are talking in theory in actual scenario.

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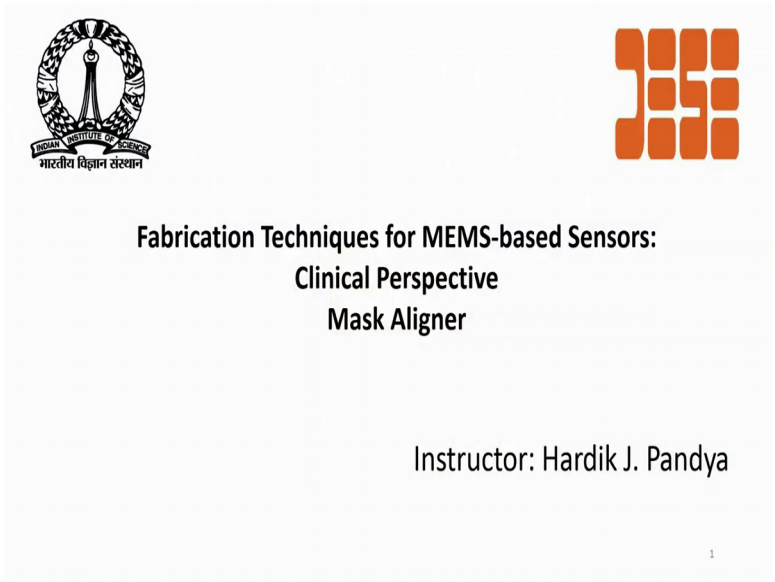

So, with that particular focus with that particular idea this today's lecture is framed. So, the name of the slide is mask aligner. So, if you see the slide, you see the screen, we will be talking about mask aligner today. And mask aligner is used for photolithography.

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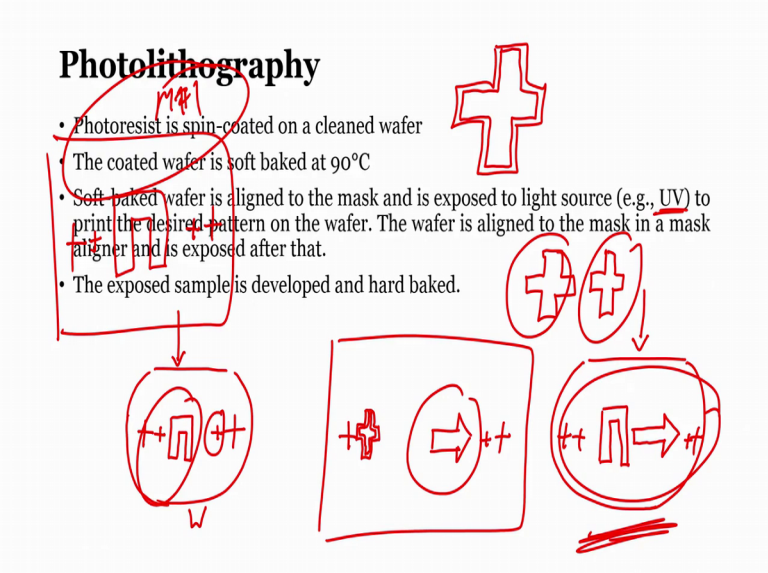

So, you have to see a slide. And the photolithography photoresist is spin-coated on a clean wafer we know it. The coated wafer is soft-baked at 90 degree we know it. Soft-baked wafer is aligned to the mask and exposed to the light source UV light right, to print the desired pattern on the wafer. The wafer is aligned to the mask in a mask aligner and exposed after that right.

So, what is alignment? So, let me just quickly tell you ok. Let us say you have, we need a pattern, which is like this. In the final wafer, this is what we need ok, this is our final wafer. So, we have done photolithography with a mask, our first mask has let us say this pattern. And with the help of this first mask, we have used photolithography to design to get this pattern on the wafer right.

Now, this mask should have some alignment mark. What is the role of this alignment mark? So, you understand right, we have first mask with this pattern, and there are alignment marks right, this is mask-1. So, our second mask mask-2 would have this pattern, this is our mask-2 right.

Now, I had to align this wafer, I have to align when I have to again perform photolithography with mass to such that I can have this kind of design, next to my arrow. So, when I am going to align this mask, my wafer with mask-2 right with mask-2 I had to load the wafer sorry I have to load the wafer, and the wafer is already having this pattern right.

Now, this alignment mark here, an alignment mark here should align properly. So, if I have my alignment mark on my wafer looks like this, and my alignment mark on my mask looks like this should align it, so that if I see it looks like the mark of the mask is exactly in the mark of the wafer. With this alignment mark, we can align the pattern in the mask. If the alignment is not proper, then this can overlap right. If the alignment is not proper, the wafer design the design of the wafer can overlap this. And will not get what we desire will not get, what we want right.

So, it is very important, how to align this thing for that we require a mask aligner. So, this is just two mask process right, mask-1, we form the pattern mask-2, we form another pattern right mask-2 was if I remove this mask-2 was another pattern using mask-1 and mass-2, we want to have this pattern. So, the alignment mark role is very important.

Another point you have to remember is always the alignment of the second mask is smaller than the first mask. If my mask-1 has a alignment mark right, my mask-2 should be the alignment mark of my of my mask two should be smaller than my alignment mark of my mask-1 that is very important to remember all right, it is very important, so remember these things.

Same way alignment mark for my mask-3 should be smaller than alignment mark of my mask-2. Alignment mark of my mask-4 should be smaller than alignment mark of my mask-3 ok. This is how we can perfectly align the different mask. Now, the wafer is aligned to the mask in a mask aligner and exposed, the exposed sample is developed and hard baked right, and finally we perform the hatching. So, this is the photolithography, we know it.

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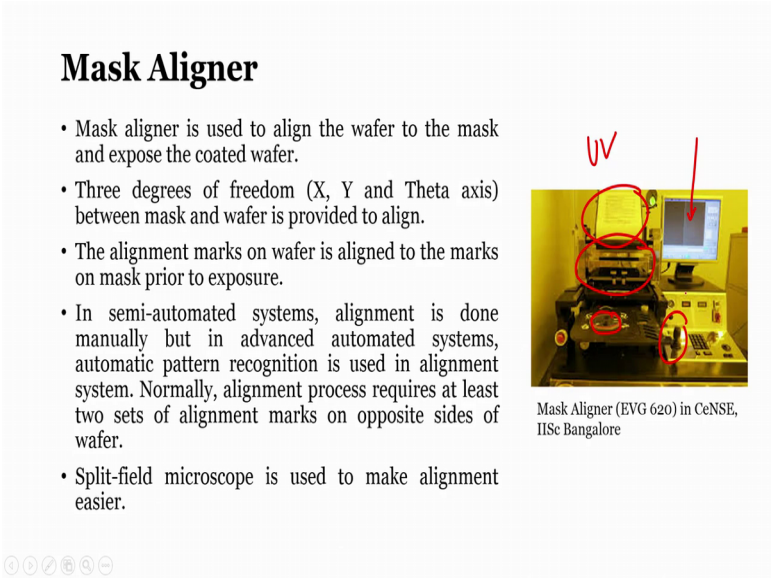

How the mask aligner looks like right? So, we see this is a mask aligner, we have it in a Centre for Nano Science and Engineering at IISC, and this is EVG 620. So, this is a mask aligner, you can see here in the display you can see how the wafer looks like, what the pattern on the wafer looks like. This is the exposure unit right, this is the exposure unit. This is where your UV lamp is kept UV lamp is kept right UV require, UV light to follow. This is a joystick to move X, Y the wafer in X and Y.

There is a theta direction for moving the wafer in theta, so X, Y theta right. And of course, this is a mask aligner which is close to as far as I understand about 80 90 lack. Some mask aligners are even like 1.5 crores, some are 2 crores right depending on the mask aligner. So, the point is mask aligner is used to align the wafer to the mask and expose the coated wafer right, coated with what photo resist.

Three degrees of freedom, we get always X, Y, and theta right. If we want to want to align the mask, so you have to move the mask either in X, Y or theta or you move your wafer in X, Y or theta. So, I you have two options either remove the mask or remove the wafer. I would prefer to move the wafer. You hold the mask, move the wafer either in X direction, Y direction or in a theta direction angle.

Now, next one is if you see the screen, the alignment marks on the wafer is aligned to the mask marks on the mask prior to the wafer right. What is that the alignment marks on wafer is aligned to the marks on mask prior to the wafer, so that is what we have taken an

example that the alignment mark of mask-2 should be smaller than alignment mark of mask-1. In semi-automated system, alignment is done manually, but in advanced automated system automatic pattern recognition is used to alignment used in alignment system.

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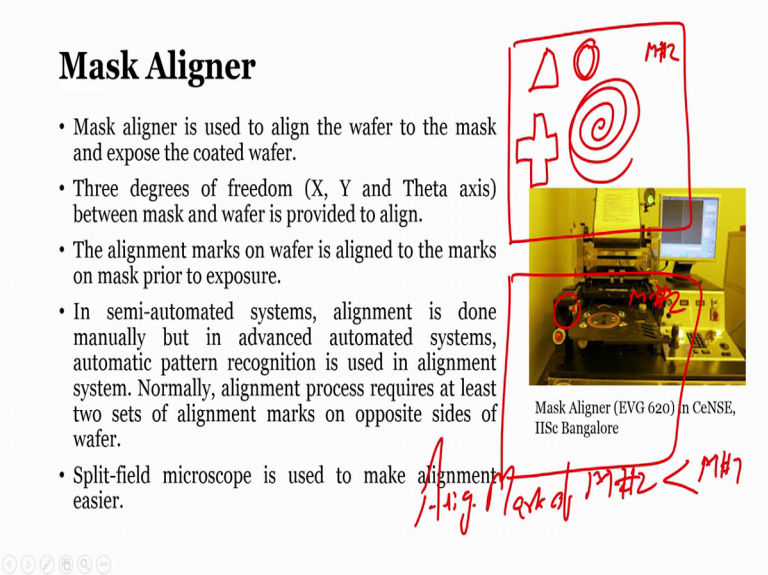

Normally, alignment process requires at least two sets of alignment marks opposite sides of the wafer, what does that mean, if I have the alignment mark right, whatever the pattern here is I require at least two alignment mark on the wafer. Now, this does not mean that every time I had to draw a plus I do not whatever the pattern is this is a metal here my alignment mark can be a plus, can be a triangle, can be a circle, can be any design right.

I just want to make sure that the mask-2 when I make the if I use a circle here, I am using a circle here right, this circle when I align it with this one, this should be within it this is mask-1, mask-2. So, alignment mark of mask-2 should be less than alignment mark of mask-1. So, this smaller than alignment mark of mark of mask one that is very important to remember ok.

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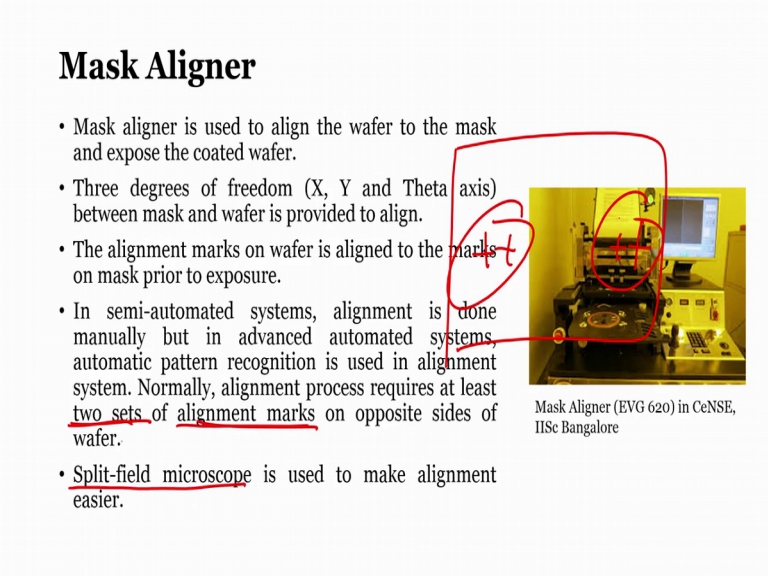

So, normally alignment process at least requires two sets of alignment marks on opposite sides of the wafer. Split-field microscope is used to make alignment easier. So, if we use split-field microscope at, if you have the wafer or if you have the mask at the same time, you can see both the areas, both the alignment mark at the same time you can use or see if we use split-field microscope, so that is another point that you need to remember, when you are using a mask aligner.

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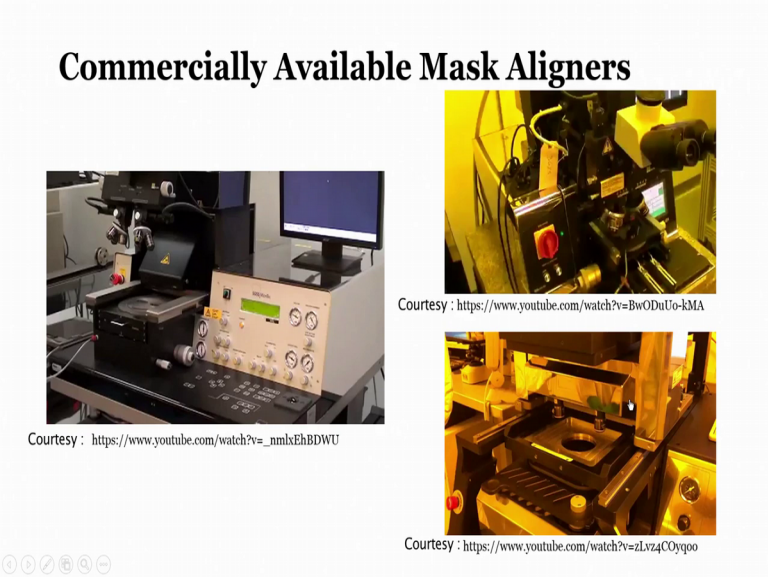

These are few commercially available mask aligner. There is a you can go to this YouTube link, and look at this how it is operated right. And then it will be easier for you to understand what is the role of mask aligner, and how we can design a mask aligner. See in this case, these are the lenses for the microscope right split-field microscope, this is the UV exposure unit right.

And this is the X, Y and theta stage right X, Y and theta stage, this is for the pressure for holding the wafer. And exposure time what is the power that you are applying this electronics is right over here, this is to move manually X, Y, Z and in this particular case again here what you see is you can see a mask holder right, and you can see a wafer.

So, there is a mask holder there is a wafer, there is a split-field microscope again here. So, just go through it, and see it again you can see very clearly, it is in yellow room, it is in yellow room, this is in yellow room you see, everything whenever you use its always should be operated in a yellow room. There is a display always connected with it, so that we can see the alignment. The alignment mark we have to see we had to adjust it accordingly right, we have to see the pattern you can see the pattern as well. So, these are commercially available my mask aligner.

Now, yeah this is a YouTube video. So, we will we will play each video, when the time permits. So, just go through each of the video, and you will understand how it is operated right. So, we have three videos here for you to observe. And let us play one by one all three videos.

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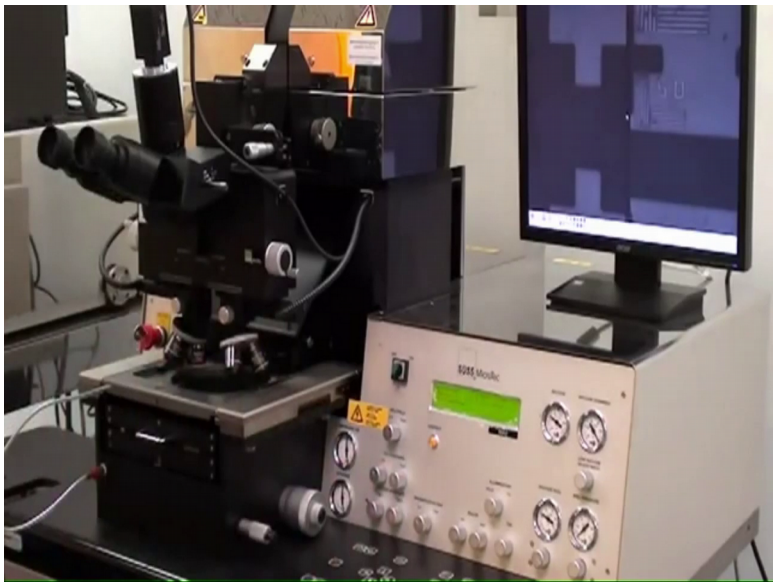

This is not a matched master wafer, but we should at least be able to see the alignment process. And I am satisfied with the alignment. So, well expose they will unload the wafer, and run the same wafer in topside alignment now. (Refer Time: 22:47) another 5 second exposure remember it.

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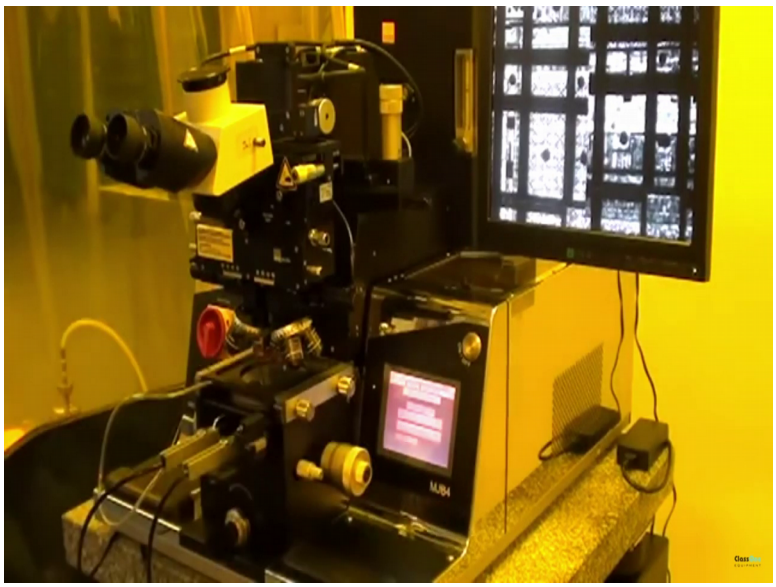

Today is April-14 2013. And we are looking at (Refer Time: 23:15) MJ before, id number 33685, serial number 191. This machines through the refurbishment process ready to be walked down for shipping. But, first well just demonstrate the operation by running a 4

inch wafer in high contact. That is contact move to the alignment can this is not match, match the wafer, but we can atleast demonstrate the alignment procedure (Refer Time: 24:16) contact because a 1 inch check, it introduces (Refer time: 24:21) wafer.

Now, we can verify the (Refer time: 24:26) alignment inorder to access both (Refer Time: 24:34) double check that you want to expose, you try download this machines also set up with higher capability. So, we can run in same wafer (Refer time: 25:05) or rather than reflected by (Refer time: 25:07) and to demonstrate that (Refer time: 25:19) switched to ion load (Refer time: 25:37) wafer by transmissive (Refer Time: 25:41) from underneath the wafer; alignment check. Turn to expose confirm, like performance the first (Refer time: 26:10) exposure.

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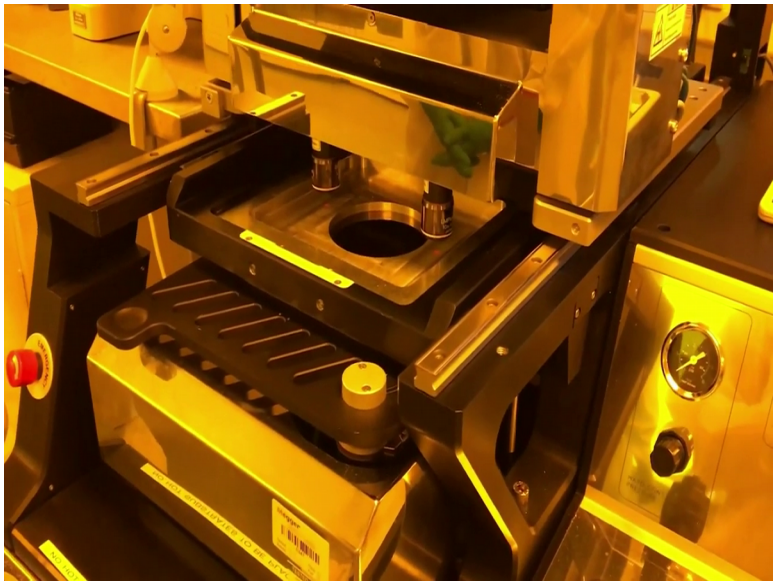

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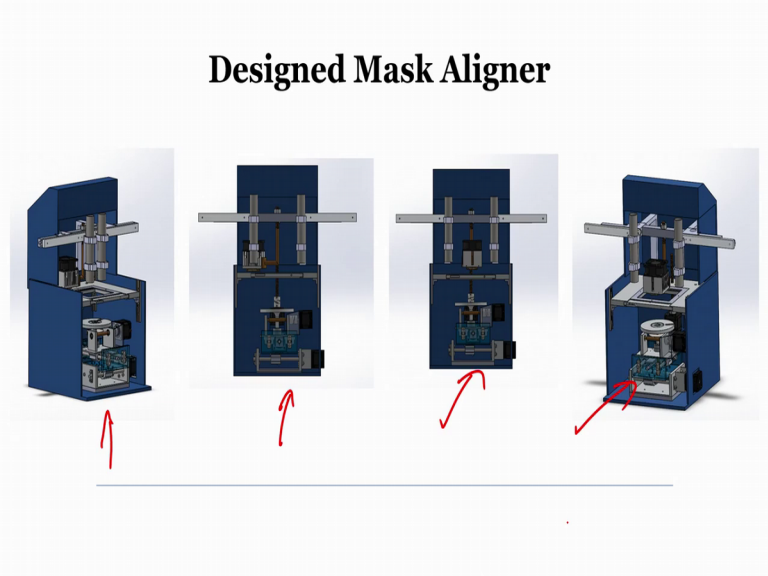

Now, since we know what a mask aligner looks like what are the designs right, there is a split-field microscopy, there is a UV exposure system, and there is a mask holder, and there is a wafer holder, and we require X, Y, theta stage for moving it. So, we can design the mask aligner accordingly right. This is our design, this is our design, and this is what we are working on to make a mask aligner which is cheaper. And that can go and we can use it in most of our laboratories or most of our universities, because this would be affordable mask aligner.

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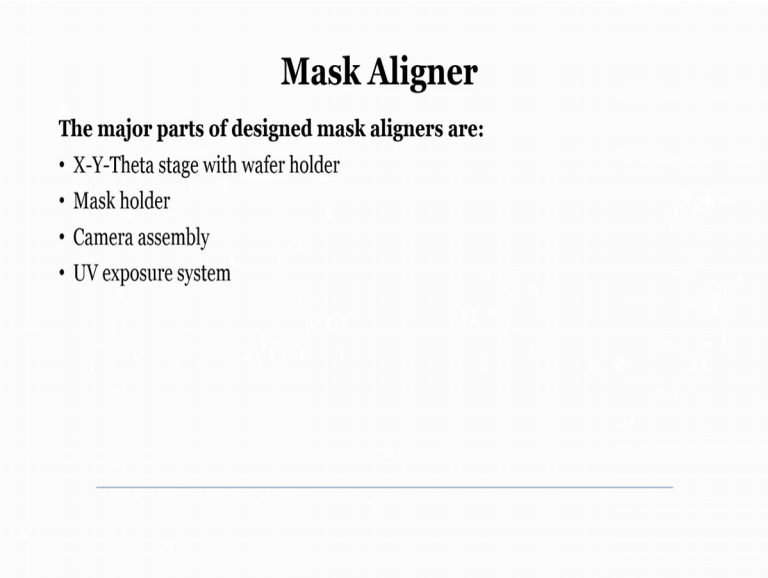

Now, to make it affordable first we are and the stage of designing it, and we are stage of fabricating it. So, I will show you few of the assembly that we have designed, and then video where how it is working.

So, for the mask aligners, the major parts of the design mask aligners are X-Y-Theta stage with a wafer holder. We have a mask holder, we have a camera assembly, and we have exposure system which is UV exposure system right. So, for X-Y-Theta for moving the wafer and it is attached with a wafer holder, so that we can move the wafer in X-Y-Theta. We have a mask holder to hold the mask, camera assembly to look at the alignment marks, UV exposure system to expose the wafer.

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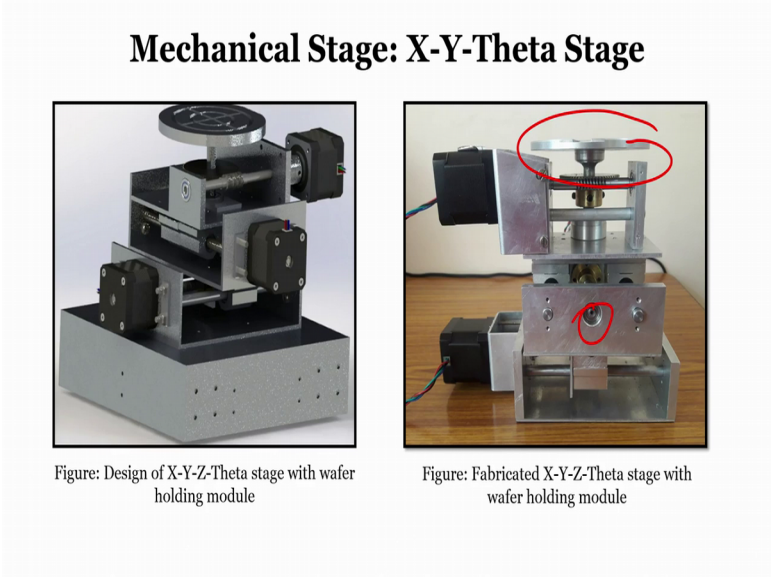

So, if I want to design this X-Y-Theta stage right, this is a 3D model right using solid works you can design using pro-e you can design right. And this is actual model, this is actually fabricated X-Y-Theta stage, there is a Z stage as well with a wafer holding model. So, we have now designed this X-Y-Theta stage.

So, you guys have to understand that using knowledge of 3D printing, there is knowledge of workshop right. We all go to a, we have a course of attending a engineering workshop right, which we understand the design, we understand the how the workshop technologies can be used. So, you can use a basic box of technologies, and you can fabricate this kind of setup. A little bit of understanding about electronic modules, and motors, and drivers is required to further operate the system. So, we have this wafer

holding system here you can hold the wafer, and you have to connect it to a vacuum system, so that you can hold the wafer correctly and when it is it will it will not move.

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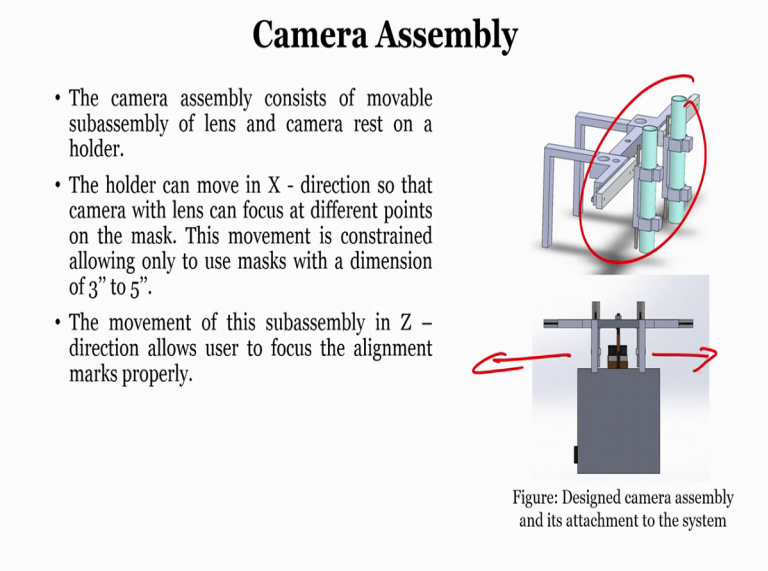

Figure: Designed camera assembly and its attachment to the system

Then we have also designed a camera assembly, what we require camera right. Camera to do what? Camera to understand the design to look at the pattern on the wafer and to align it. So, camera assembly consists of a movable sub assembly system, this can be moved right.

In a camera rest on a holder, the holder can move in X-direction, so that camera with lens can focus at different points. And it will move in this direction or it can move in this direction or to holder separately. This moment is constrained allowing only to use mask with dimension to of 3 inch to 5 inch. So, we cannot use a mask which are bigger than 5 inch and or smaller than 3 inch. The moment of this sub assembly in Z-direction allows user to focus the alignment mask properly right.

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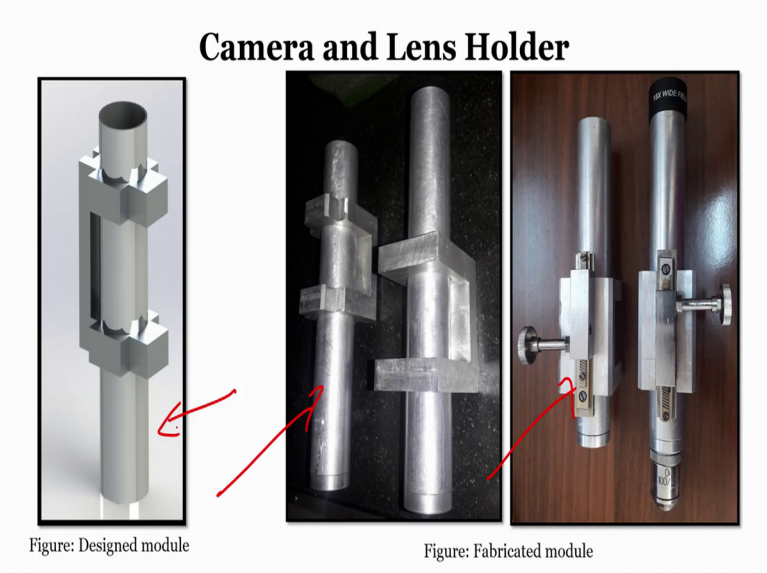

So, if you see the camera lens holder right, this is how the lens holder looks like in an actual system you can see here, this is a fabricated camera lens holder fabricated module, and this is a design module. So, from design to fabrication you can do it in your laboratory in your college, there can be a project mini-projects right.

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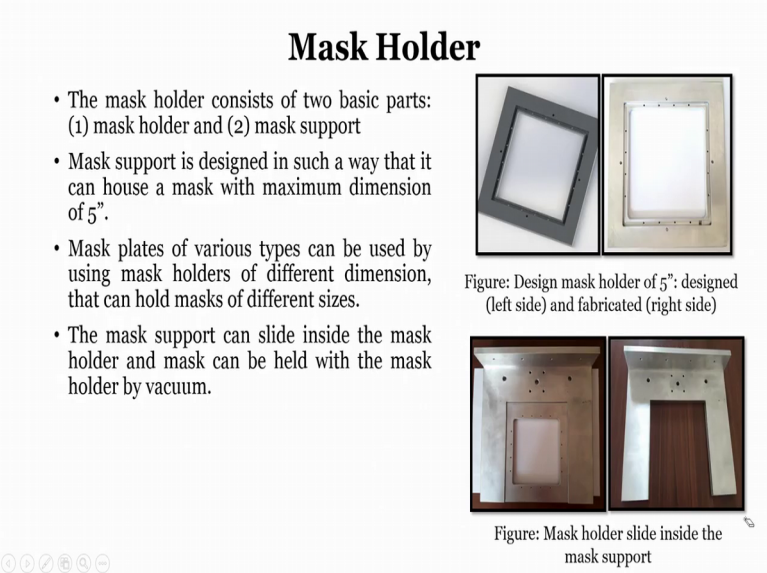

Then we have a mask holder. So, mask holder again you have to hold the mask. So, you have to create these holes for vacuum, so that the mass can be holded perfectly. This is a design mask holder of 5-inch right, left side is designed, and right side is a fabricated

version. The mask holder slide inside the mask support, so to support this mask holder, we had to insert in the mask holder slide.

The mask holder consists of two basic parts as you can see mask holder, and mask support right. Now, this is what we are showing is similar kind of a technology is used in actually available mask aligner right. Of course, with a little bit advanced version, but the idea is same idea is same. So, it is very important if you see this, you will you understand what they have used in their particular system. So, the mask holder consists of mask basic parts. One is (Refer Time: 32:25), second is mask support.

Mask support is designed in such a way that it can house a mask with maximum dimension of 5-inch. Second is mask plates of various types can be used by using mask holders of different dimensions. Third one is the mask support can slide inside the mask holder and mass can be held with the mask holder by vacuum right. So, this is about the mask holder.

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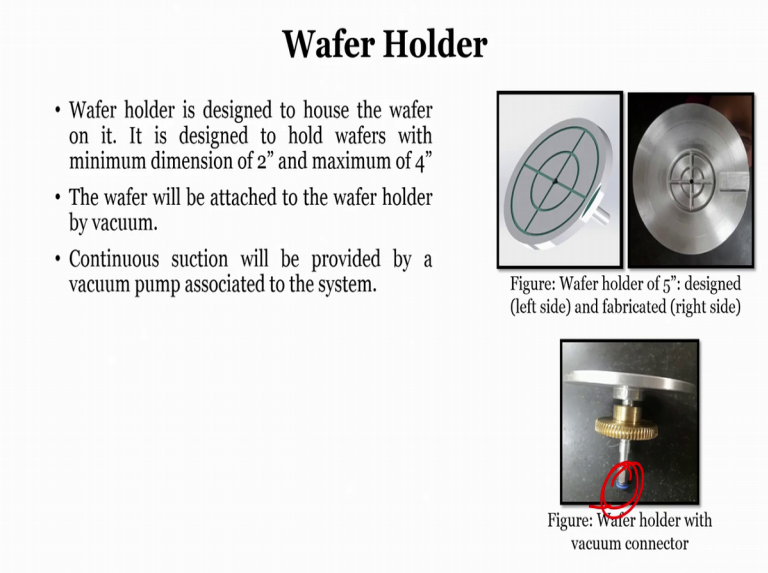

Now, if you go further, there is a wafer holder. Once we have a mask holder, we also require a wafer holder. Now, how does exactly wafer holder works? Wafer holder is designed to house the wafer on it right. So, here you see here, again we had to create a vacuum, so that the wafer can be hold it these wafer holder of 5-inch design and fabricated.

Actually, the wafer holder we have wafer for 4-inch right were mask is of 5-inch. So, it is designed to hold wafers with minimum dimension of 2-inch and 4-inch. The holder can be 5-inch, but the mask that we can load a maximum is 4-inch ok. So, it can hold 2-inch and 4-inch wafer, the wafer which we attach to the wafer holder by vacuum.

Continuous suction will be provided by a vacuum pump. So, you had to connect a vacuum pump here right, wafer holder with the vacuum connector you can see here, and this needs to be connected to a vacuum pump so to again enough vacuum to hold the wafer. It should not be such that the wafer will get crack or break that is another thing that is very important that we when we design the wafer holder.

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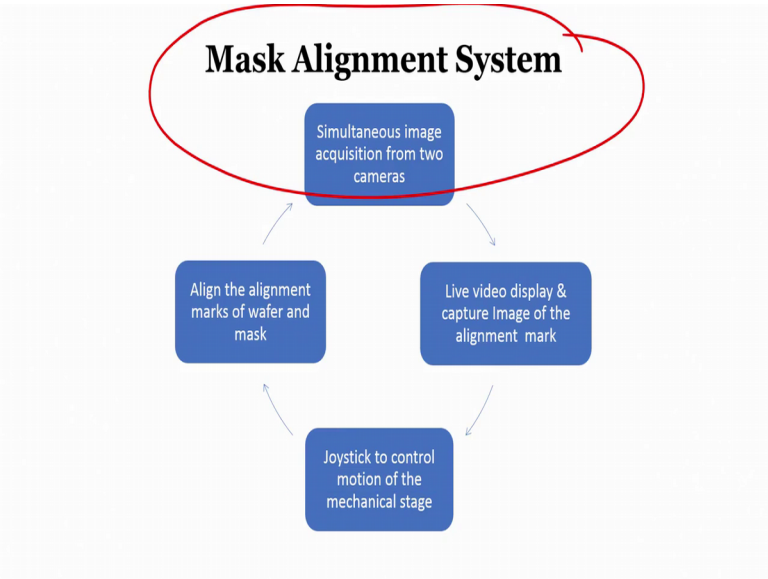

Now, when you talk about the mask alignment system, what you see, you have to have a simultaneous image acquisition from two cameras right simultaneous acquisition of images from two cameras. Then we should have a live video display and we should have a capability of capturing image of the alignment mark. Then we should have a joystick to control the motion of mechanical stage, and we should have the; we have to align the alignment marks of wafer and mask. These are the requirement requirements for the mask alignment system right more or less of a mask alignment system.

So, if we can address all these three requirements, we can design the mask alignment system. So, how we can design this mask alignment system, and how we can interface

this to actual display, and then what kind of UV source we can design, so that we will talk in the next module.

For this module, you understand that the mask alignment system or the mask aligner is a very important part of a photolithography system. And we are learning how to quickly design a mask aligner or I am showing it to you how the mask aligner can be designed right. So, in the next module, we will see the next portion of the mask aligner, and see how it can be used in actual scenario.

Till then you take care, look at the module, I will see in the next class. Bye.